# 第一章 台灣島的形成

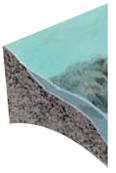
台灣島除了四面環海，地形更是變化多端。呈南北走向的中軸是高聳巍峨的中央山脈，西側山巒旁則遍布高低起伏的丘陵地形，緊接著就是平坦遼闊的西部平原，還有夾於中央山脈與東部海岸山脈之間狹長的花東縱谷。這種種台灣島的豐富面貌，不禁引發人們的好奇心：究竟是什麼原因造成了這個美麗的寶島呢？

## 台灣板塊構造運動

若要解釋台灣島形成的過程，必須先認識台灣的板塊構造運動背景，並藉此了解台灣地質歷史的演化過程。

從衛星影像鳥瞰台灣，可將台灣全島一覽無遺（圖1-1）。台灣看似一個孤立在海上的島嶼，但是若將海水抽除，從地體構造上直接觀測地殼表面及地下深處，會發現台灣正處在一個地質構造相當複雜的位置上；除了位於菲律賓海板塊與歐亞板塊的交界帶上，東南方有呂宋島弧系統、東北方有琉球島弧系統，台灣其實就是呂宋島弧與琉球島弧的轉接點（圖1-2、1-3）。板塊的擠壓作用，決定了這兩個島弧系統的發育、演化過程，更決定了台灣今日的面貌。

■圖1-1 台灣衛星影像。
■Fig1-1 The satellite image of Taiwan island.



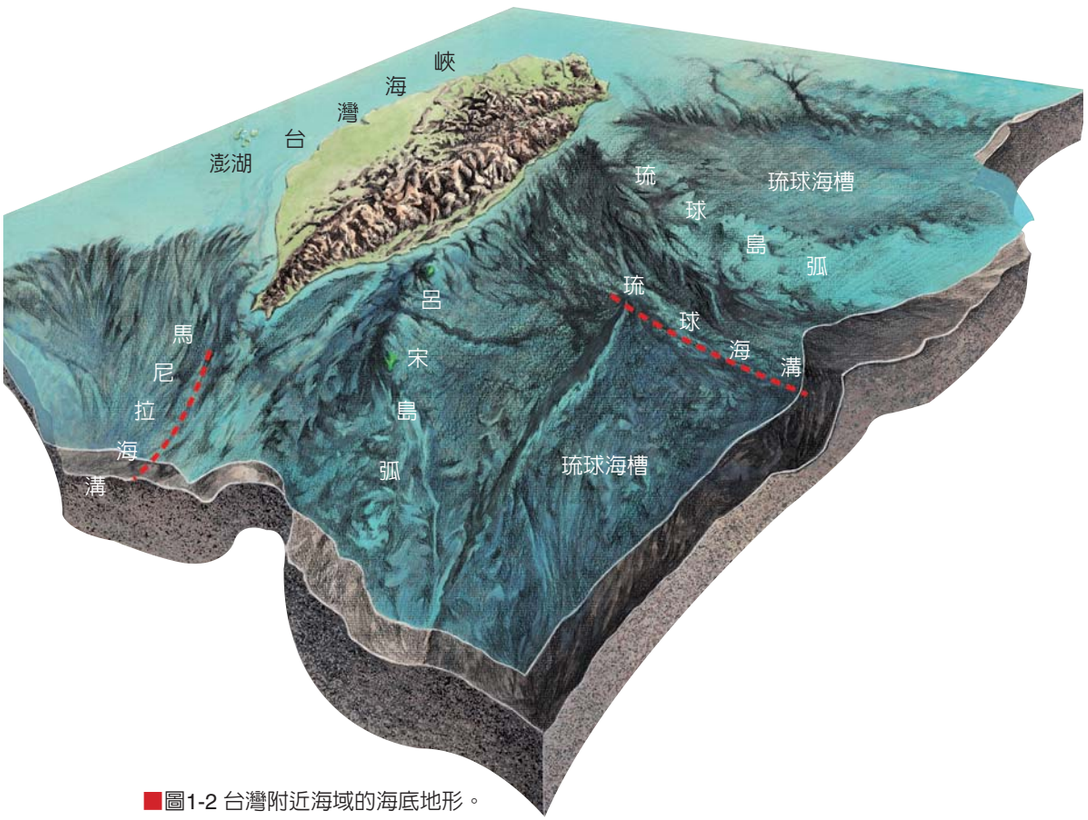
### 一、 呂宋島弧的形成

大約三千五百萬年前，歐亞板塊的東南緣開始張裂。這個張裂作用非常劇烈，使整個歐亞板塊被撕裂開來，而來自地函的岩漿沿著裂隙向上湧出，在現今南海附近生成一塊新的海洋地殼，

How was Taiwan formed？In the satellite photo, Taiwan is a narrow NS trending island with dramatic change in elevation. The high mountain chains run through the center of the island, which rise up steeply from the east coast and drop rapidly to foothills and then flat coastal plains in the west.

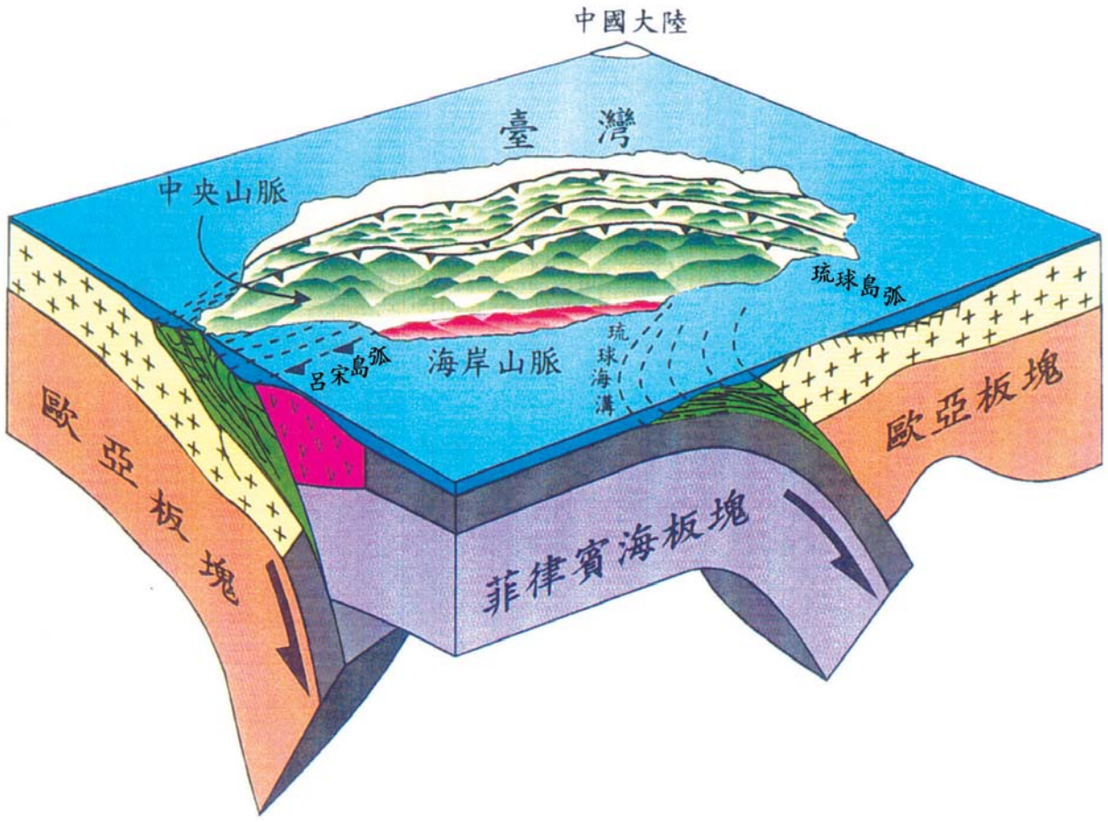
## Plate tectonic history of Taiwan

Although Taiwan seems like an isolated island from the satellite image (Fig.1-1), it has complex association with other tectonic plates with complex deformation history. If we remove the sea water, we can see that Taiwan situates at the plate boundary of the Philippine




■圖1-2 台灣附近海域的海底地形。

■Fig1-2 Sea floor morphology in the vicinity of Taiwan.




■圖1-3 台灣島的地體構造。
■Fig1-3 Lithospheric structure of Taiwan.

地質學家就稱它為「南海地殼」或「南海板塊」。

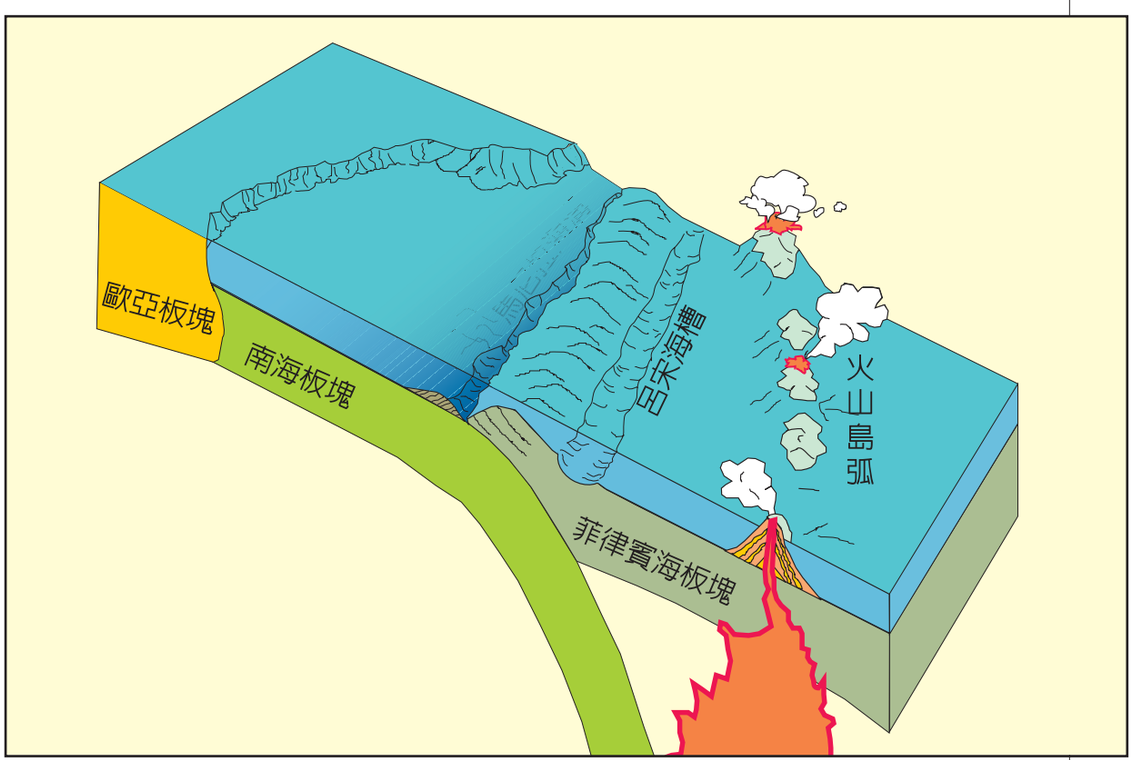
約兩千萬年前，由於南海板塊繼續地張裂並向東移動，遇到了正向西移的菲律賓海板塊。當兩個海洋板塊相互擠壓時，其中之一會隱沒至另一板塊之下，當時南海板塊就隱沒至菲律賓海板塊之下（圖1-4）。當隱沒的板塊在另一板塊下方向下移動時，會造成地函物質產生部份熔融生成岩漿，這些岩漿又會沿著上方板塊的裂隙上升噴出地表形成火山。這些火山常呈線狀或弧狀排列，故以「火山島弧」稱之，也就是地理上的「花采列島」。

在兩個板塊交界處，隱沒的地方，在海板塊一側形成海溝且深度較大；而另外在大陸板塊一側，往往會略微下陷，水深較海溝為淺，稱為「海槽」。呂宋島弧、馬尼拉海溝及呂宋海槽系統就是這樣生成的。

Sea plate and the Eurasia continent, at the connecting point of the Ryukyu Arc to the north-east and the Luzon Arc to the south-east (Figs 1-2 and 1-3). The plate tectonic evolution between the Philippine Sea plate and the Eurasia continent not only determined the formation of the Ryukyu Arc and the Luzon Arc, but also determined the formation of Taiwan.

## Formation of Luzon Arc

The upwelling magma from mantle tore up the southeastern edge of Eurasia continent during 35Ma and formed a new oceanic plate named the South China Sea plate. The South China Sea plate continued to grow and migrate eastward till it collided with Philippine Sea plate and under the westward moving Philippine Sea plate




■圖1-4 台灣島的生成。

■Fig 1-4 Formation of Taiwan island

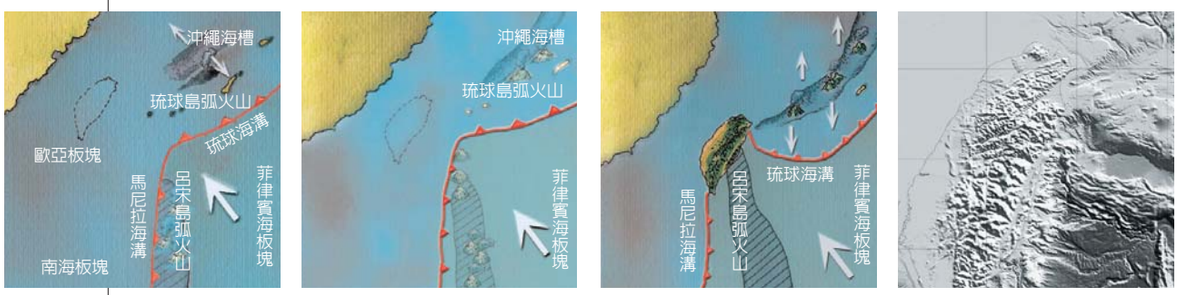
## 二、琉球島弧系統的形成

菲律賓海板塊位在歐亞板塊的東南方，在這裡，歐亞板塊的邊緣大致上是東北—西南走向的。當菲律賓海板塊每年以7公分的速度向西北移動時，最後遇到了東北走向的歐亞板塊邊緣。當兩個板塊相遇後，密度較大的菲律賓海板塊就下沉，向北隱沒至歐亞板塊之下，而形成了琉球海溝、琉球島弧、沖繩海槽系統（圖1-5、1-6）。

# 弧陸碰撞——蓬萊造山運動

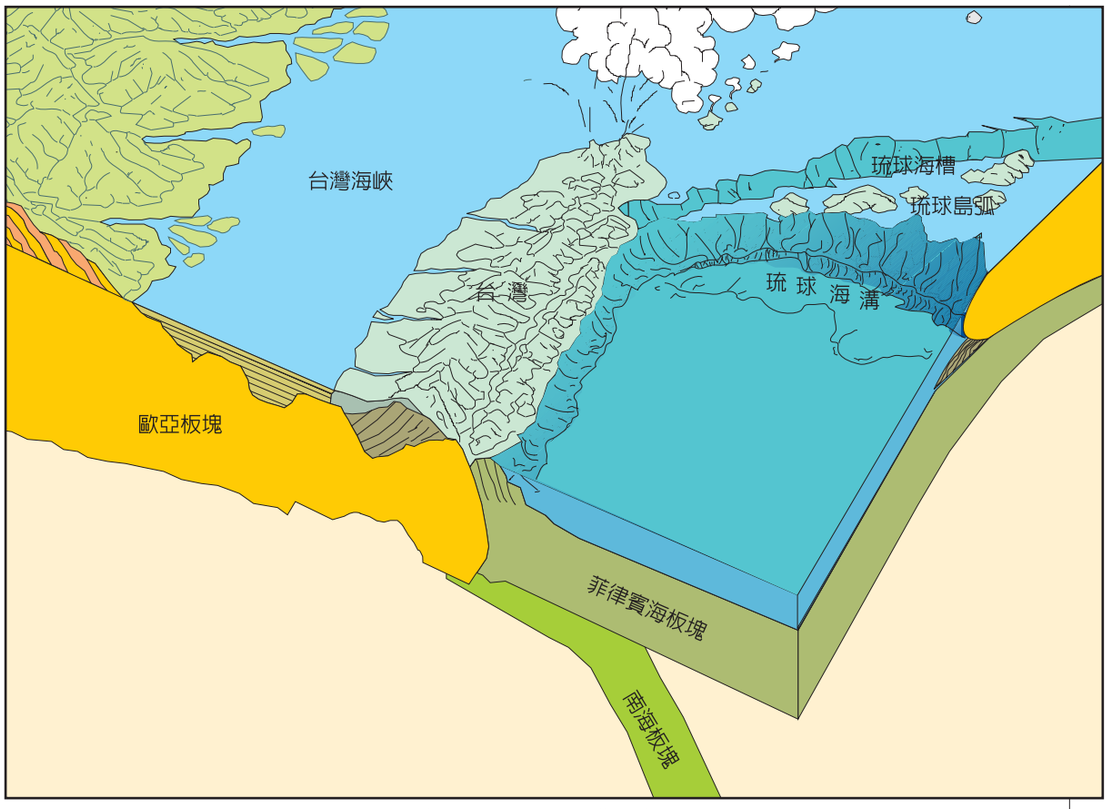
依據板塊構造學說，大陸與大陸地殼或大陸地殼與島弧的碰撞作用會形成山脈。在碰撞帶所形成的高聳山脈，如亞洲的喜馬拉雅、歐洲的阿爾卑斯以及北美洲的阿帕拉契山脈，這些全球著名的山脈就是大陸地殼與大陸地殼碰撞的結果。而在台灣的東南亞第一高峰玉山，則是大陸地殼與島弧碰撞所形成高山中一個最佳實例。

這個主要由呂宋島弧與歐亞大陸地殼碰撞所引發的造山運動，稱之為「蓬萊造山運動」。從六百萬年前開始，由於呂宋島弧隨著菲律賓海板塊持續地向西北移動，終於斜碰上了歐亞大陸板塊。如前所述，菲律賓海板塊在北邊隱沒至歐亞板塊之下；而在菲律賓海板塊西邊的一角，受到南海板塊牽引的影響，歐亞大陸板塊卻一反常態地沒入菲律賓海板塊之下；也就是說，菲律賓海板塊沿著馬尼拉海溝以西北方




■圖1-5 琉球海溝、琉球島弧、沖繩海槽系統的生成過程。

■Fig.1-5 Formation sequences of the Ryukyu arc / trench system




■圖1-6 台灣西北側菲律賓海板塊隱沒帶與琉球島弧、琉球海溝及沖繩海槽相關位置圖。
■Fig.1-6 Geographical location and relation of the subduction zone NW Taiwan, the Ryukyu Arc / trench system and the Luzon Arc / trench system.

around 20 Ma (Fig.1-4). Volcanoes tend to line up in chains parallel to the subduction boundary often referred to as volcanic arcs. A trench and trough system often accompanies a volcanic arc. For example, the deep Manila trench formed along the subduction side of the Luzon arc; while the shallow Luzon trough formed on the other side due to slight sinking of the Philippine Sea plate (Fig. 1-4).

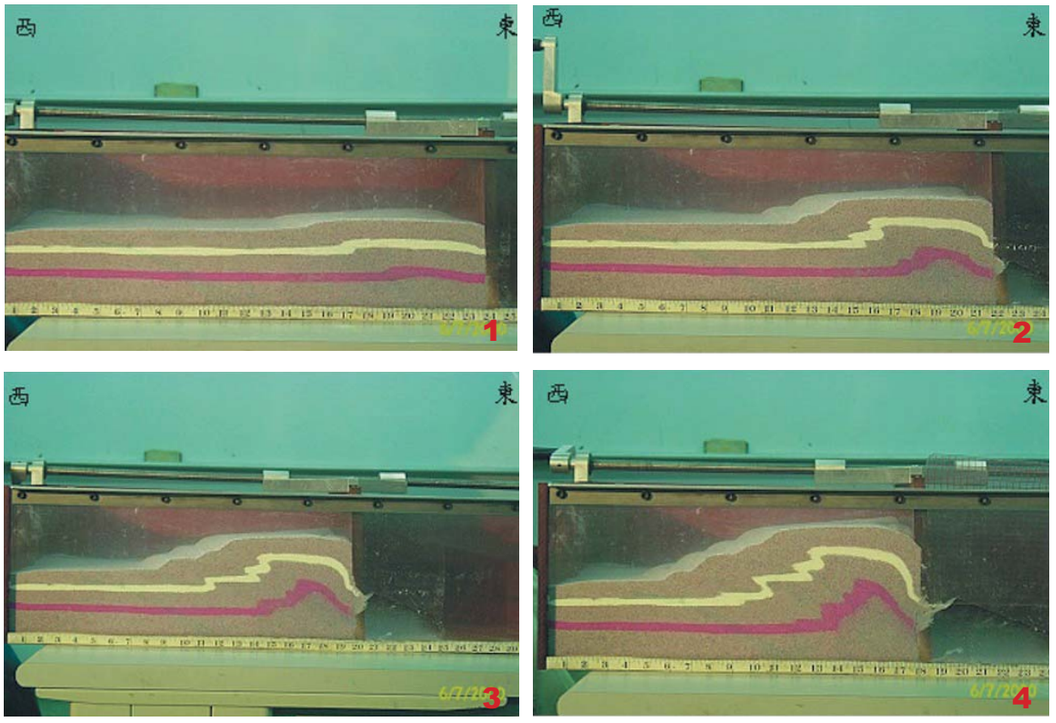
## Formation of Ryukyu Arc

Similar to the Luzon Arc system, the Ryukyu Arc system formed by collision between the Eurasia continent and the northwestward moving (at a speed of 7 cm/year) Philippine Sea plate. With much higher density than the Eurasia continent, the Philippine Sea plate

向仰衝至歐亞板塊之上。所以，在台灣地區，向下俯衝的是亞洲的大陸地殼。但是大陸地殼的比重較輕，不像海洋地殼能順利地進入隱沒帶，因此與呂宋島弧碰撞而被擠壓產生褶皺、斷層、抬升，使原本沉積在海底的沉積物，逐漸隆起露出海面，造成台灣今日的山脈。

至於台灣山脈、丘陵、海岸平原生成的過程，我們可以利用沙箱來實驗、模擬造山運動的進行。在實驗中，沙箱的隔板代表菲律賓海板塊，沙箱中平鋪的沙層代表亞洲大陸邊緣的海底沉積物。當隔板向西逐漸推進時，靠近隔板處，首先被推高、發生褶皺、斷層。當隔板持續向西推進時，第二個褶皺、第二個斷層也發生了；向西依序第三、第四、第五、第六個褶皺與斷層也相繼發生（圖1-7）。

值得注意的是斷層依序由東向西發生，新產生的斷層都是以低角度出現，之前發生的斷層則被抬升且斷層角度增大。當第四、第五、第六條斷層出現時，之前的老斷層受到前緣年輕斷層上盤砂層褶皺的




■圖1-7 沙箱模擬碰撞帶的造山運動。

■Fig.1-7 Sand box simulation of orogenesis through arc-continent collision.

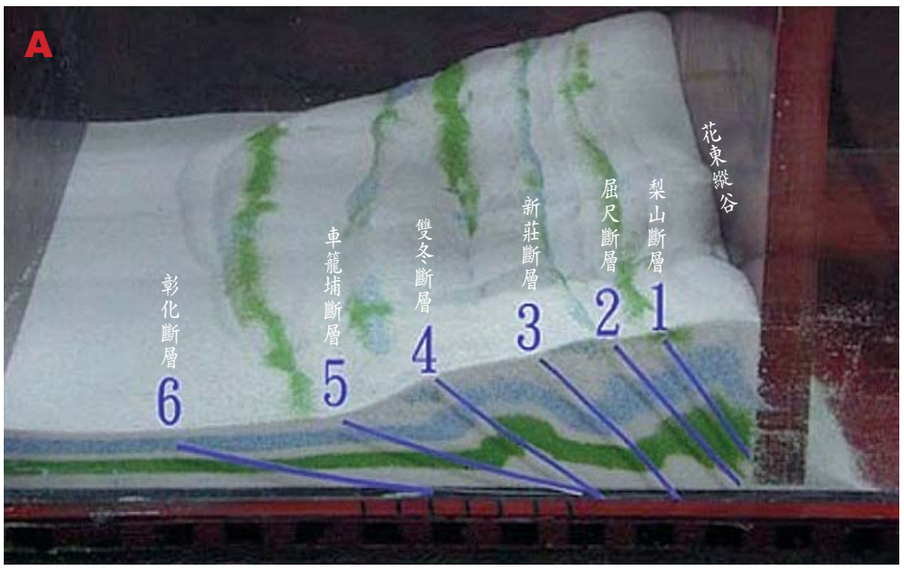
subducted northward under the Eurasia continent, forming the Ryukyu trench at the south of the Ryukyu Arc, and the Okinawa trough to the north (Figs1-5 and 1-6).

## Arc-continent collision: Peng-Lai Orogeny

How were the magnificent mountains, such as the Himalayas, Alps, and Appalachians formed, had long been a puzzle to geologists till plate tectonic theories. Now we know the mountain formation is caused by (1) continent - continent collision, such as the Himalayas, Alps, and Appalachians, or (2) continent - arc collision, such as Yu Shan, the highest mountain in Taiwan. The Peng-Lai orogenesis started around 6 Ma when Luzon arc began to collide with the Eurasia continent. As aforementioned, the northern edge of the Philippine Sea plate submerged under the Eurasia continent; while the western edge of the Philippine sea plate pilled up northwestward on top of the Eurasia continent due to the presence of the South China Sea plate. With lighter Eurasian continent submerged under the denser Philippine Sea plate, violent uplifting of the original marine sediments with active folding and faulting began when the continental material cannot be pulled down any further. These material started to rebound up through the sea level, forming mountains.

A sand box simulation clearly illustrated the deformation history of mountain belts and foothills in Taiwan (Fig. 1-6). The division plate represents the Philippine Sea plate, and the horizontal sand layers

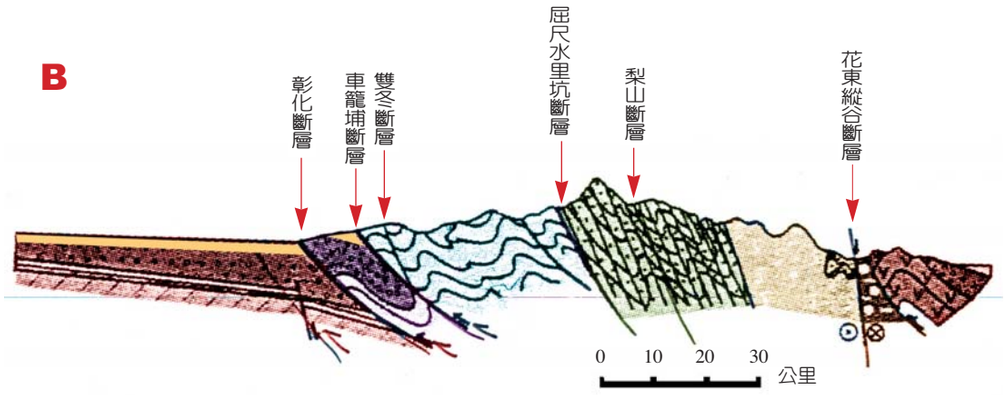
影響，而被褶曲、旋轉和抬升形成覆瓦構造。地層褶曲更加劇烈時，各層因推擠而變厚，砂層則因逆衝斷層堆疊而增厚形成一個近似三角的楔形體。以台灣中部的地質剖面比較觀之，大體上是相當吻合的（圖1-8A、1-8B）。




■圖1-8A 沙箱模擬實驗結果與台灣主要斷層相關位置對照圖。

■Fig.1-8A Diagram showing the location of major faults of Taiwan according to sand box simulation.

represent the marine sediments of the Eurasia continental margin (Fig. 1-6). First sign of crustal thickening with folding and faulting occurred along the region next to the division plate when it was first pushed towards northwest (Fig. 1-7). Continuous pushing plate generated multiple generations of folding and faulting successions . Intriguingly, these new generations of faults all migrated from east to west at low angles. The older generations of faults, however, are folded, rotated, pilled and tilted steeply by younger faults. These features are commonly seen in cross sections of central Taiwan (Figs 1-8A, and 1-8B).




■圖1-8B 台灣中部地質剖面圖。（修改自鄧屬予，2002）

■Fig. 1-8B Geological cross section of central Taiwan.